# *Petrological Abstracts and Reviews*

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LEITH, C. K. and MEAD, W. J. *Metamorphic Geology.* Henry Holt & Co., New York, 1915. Pp. xxiv+337, figs. 35, pls. 16.

This is one of the most valuable of recent petrologic textbooks. The experience of the authors in the interpretation of metamorphic processes would make this work of great value even though there were many books on the subject; since this is actually the only general textbook, it is doubly valuable and welcome.

Under the term rock-metamorphism the authors include not only the changes involved in the formation of rocks commonly called metamorphic, but also all mineralogical, chemical, and physical changes which have taken place in rocks subsequent to their primary crystallization from the magma, thus including in the definition cementation and rock-weathering. In other words, the metamorphic processes here included are both the destructive processes of katamorphism and the reconstructive processes of anamorphism, together forming the metamorphic cycle.

The writers take up first the katamorphism of acid igneous rocks, katamorphism being used "to cover all alterations of a disintegrating or decomposing nature, whether accomplished by weathering or by thermal solutions, whether at the surface or below." The most important phase of katamorphism is weathering, or the alteration of surface rocks by the agencies of the atmosphere and hydrosphere. By this process the rocks decompose and disintegrate, and part of the constituents are carried away in solution, while the residue forms a porous mass which in many cases retains the texture of the original rock. Clay, sand, carbonate, and salt in aqueous solution are the end-products of katamorphism. Chemically the changes are chiefly hydration, carbonation, oxidation, and desilication; mineralogically there is a destruction of some minerals and a simplification of others, the minerals in many cases passing through intermediate forms before reaching the simple end-products. Another change produced is one of volume, there being an increase by the formation of pore space, by the addition of water,

carbon dioxide, and oxygen, and by the decrease in the average specific gravity of the minerals formed.

The authors do not lay much stress upon the zones of katamorphism and anamorphism, emphasized by Van Hise, for the zone through which katamorphism extends, for example, has very indefinite limits, both katamorphic and anamorphic changes being possible simultaneously at moderate depths in different kinds of rocks, or in the same kind of rock under different conditions.

The weathering of granite is used as a type of katamorphism. The rock used as an example is a Georgia "granite," and although so called by Watson it is not a granite, neither mineralogically as shown by the table on page 6, nor chemically. It is a quartz-monzonite verging toward a granodiorite, and not greatly different from Lindgren's type granodiorite. So far as the results of the alteration go, however, it is immaterial what the rock is called, and the term granite may be used in the "commercial sense." In this chapter 16 pairs of analyses, representing the weathering of acid igneous rocks, are shown by "straight-line diagrams," which well illustrate the changes which have taken place.

The second chapter treats of the katamorphism of basic igneous rocks, 17 pairs of analyses being given in the second plate.

In the third chapter the production of bauxite and laterite by the extreme weathering of rocks is discussed, the authors maintaining that bauxite and the associated clays are the products of the surface weathering of syenite by normal processes of rock-decomposition, and that they are not chemical sediments. They believe that kaolin is an intermediate stage and that they can trace the gradation from syenite through kaolinized syenite to bauxite wherever fresh cross-sections appear. There is a good discussion of the formation of laterite and associated iron ores in Cuba.

A comparison of the two plates showing the hydrothermal katamorphism of 29 igneous rocks with the plates showing normal weathering gives a clear conception of the differences between these two types of alteration.

So far the book has dealt with the katamorphic destruction of igneous rocks and with the nature and distribution of the end-products. The katamorphism of sediments, ores, etc., is now taken up in several chapters, and is followed by 30 pages on the redistribution of the constituents of the average crystalline and igneous rocks during katamorphism. Here the redistribution of the constituents is considered in terms of sediments—first in weight proportions of shales, sandstones, and

carbonate rocks, then in terms of minerals, and finally in terms of chemical constituents.

For example, it is determined that the average analyses of shale, sandstone, and limestone should be combined in the proportions of 81.7, 12.05, and 6.25, or in round numbers 82, 12, and 6, to give an analysis as nearly as possible like that of the average igneous rock. If the average igneous rock is represented by some combination of granite and basalt, these being the most widespread types of igneous rocks, it should be possible, say the authors, to determine what proportions of granite and basalt will give an average that could be approximated by some combination of shale, sandstone, and limestone. For their granite and basalt analyses they use the average values computed by Daly. But this brings in a loose use of the terms granite and basalt, due to the fact that Daly's averages were computed from analyses of rocks which were not in every case actually granites and basalts but which had simply been given these names (in many cases certainly not in their modern sense) by the various geologists describing them. Instead of using these average analyses, it would have been much better if analyses only of rocks which are unquestionably granite and basalt had been used, even if they had been fewer in number. Thus the analysis on page 66, recomputed into the modal minerals (page 74), gives for granite a rock containing but 17 per cent of orthoclase while it carries 35 per cent of oligoclase ($Ab_{74}An_{26}$), besides biotite 6, muscovite 6, hornblende 2.5, quartz 31, magnetite 1.7, and ilmenite 0.3. The proportions of orthoclase to oligoclase are 17:35.5, making the rock a granodiorite, according to Lindgren's original definition, but just over the line from quartz-monzonite. (The orthoclase here forms 32.4 per cent of the total feldspar; Lindgren's division line is $33\frac{1}{3}$ per cent.) The basalt, also, has for its modal feldspar oligoclase ($Ab_{70}An_{30}$), and has 10.7 per cent orthoclase, besides augite 37, olivine 7.6, magnetite 5.8, ilmenite 0.73, and titanite 2.8. For a basalt the plagioclase is decidedly sodic, and the rock should rather be called a melanocratic orthoclase-bearing olivine-diorite. Comparing the modal minerals of these rocks with those in Clarke's average igneous rock, the authors found that the latter was too low in quartz, assuming that the normative quartz in 84 granites (Q=32.8) is the same as the modal. But normative quartz is almost invariably higher than modal. If analyses of true granites and true basalts were used instead of granodiorite and orthoclase-bearing olivine-diorite, the authors' and Clarke's averages would be more nearly alike. It is true that the modes given for these rocks were calculated from the

analyses, but the authors themselves say the computations represent "as nearly as possible the actual mineral composition of the rocks." Changing the granite (granodiorite) and basalt (diorite) analyses would probably give a different result for the average sediment, the proportions now found being 65 granite to 35 basalt.

Under the term anamorphism are included cementation, metasomatic replacement, rock-flowage, contact and thermal metamorphism, and the constructive changes which tend to make rocks coherent and crystalline. The anamorphism of clays through shale, slate, and schist to the contact phase, and of sands to sandstones and quartzites, and limestones to marble are all shown by numerous straight-line diagrams. Dolomitization is briefly touched upon.

In the fourth chapter of Part II, the dynamic and contact metamorphism of igneous rocks (rock-flowage) is treated. Changes produced in katamorphosed products of igneous rocks are clearly anamorphic, but igneous rocks do not necessarily pass through a katamorphosed state before becoming schists and gneisses. In such cases the katamorphic agents must in some way be simultaneously introduced. Alteration by hot water in the deeper zones is essentially anamorphic.

In the chapter on the textures and structures of dynamic metamorphism, rock-cleavage is regarded as the result of the orientation of mineral-grains or of the parallel arrangement of mineral-cleavages. The orientation of the mineral-grains is ascribed by the writers to differential pressures which caused the rock to flow. Recrystallization and the development of new minerals at right angles to the pressure and granulation and rotation of original minerals from random positions are also contributing factors in producing schistosity.

Secondary porphyritic textures, as shown by garnets, staurolite, andalusite, etc., are thought to have been caused by recrystallization, which took place after rock-flowage had ceased but while the rock was probably still under high pressures and temperature. The development of gneissic textures is considered, and Becke's and Grubenmann's views on the conditions of development of the crystalline schists are presented.

Part III treats of the determination of the origin of the metamorphic rocks. The first two parts of the book were devoted to the changes produced by metamorphism in sedimentary and igneous rocks. In this part the field and laboratory methods used in determining the origin of these rocks are discussed. Only four pages are devoted to the criteria of origin of sediments and residual rocks; a thorough treatment of this

part of the subject, say the authors, would involve the consideration of a wide range of conditions entering into sedimentation, such as is beyond the scope of the book. Twenty-two pages are devoted to primary gneisses and schists; the term primary gneisses being used for banded igneous rocks whose banding was produced during the consolidation of the rocks (ortho-gneisses, in part), and metamorphic gneisses for those that were formed by anamorphic processes (para-gneisses, in part). Among the criteria given for distinguishing primary from metamorphic gneisses are field relations, textures and structures, and mineral and chemical compositions. Instructive triangular diagrams are given showing the igneous or sedimentary characteristics of a rock.

A number of chapters are devoted to ocean, lake, river, and underground solutions as by-products of the metamorphic cycle; and there is a discussion of the metamorphic cycle as a basis for the genetic classification of commercial mineral products.

The last chapter of the third part deals with the net results of the metamorphic cycle, and the answer to the question, "Is the metamorphic cycle closed?" is that "adequate evidence of it is lacking . . . . such evidence as there is points rather toward the incompleteness of the cycle."

The fourth part, on laboratory work in metamorphism, is one of the most useful and instructive in the book. It treats of the megascopic and microscopic study of specimens and the measurement of specific gravity and porosity, a plate being given for calculating the porosity from the moisture of saturation and the specific gravity of the rock materials. It shows how analyses may be compared to determine the relative and absolute gains and losses of constituents, and gives instructions for the use of various straight-line and circular diagrams. There are instructions for comparing analyses by means of rectilinear coordinates, and for constructing triangular diagrams of various kinds. The determination of mineral compositions of rocks from their chemical analyses by recalculation or by the mineral slide-rule, and the calculation of volume- and energy-changes are treated, and finally there are suggestions for laboratory study.

The book is strongly recommended, not only to students of metamorphic geology, but to all students of petrology and to advanced students in economic or general geology. The authors are to be congratulated on having presented the subject in a clear, simple, and, at the same time, most interesting way.

LEISS, C., and SCHNEIDERHÖHN, H. *Apparate und Arbeitsmethoden zur mikroskopischen Untersuchung kristallisierter Körper.* Handbuch der mikroskopischen Technik, Part X, pp. 94, figs. 115.

A manual giving in simple form the more important apparatus and methods for the microscopical determination of crystals. The authors say in the preface that the book is intended only for the use of amateurs, teachers, and collectors of minerals who wish to make use of the polarizing microscope. It is, however, a book that can be read with profit by the average student of petrology. The authors not only deal with the polarizing microscope, but describe the preparation of thin sections, the use of the axial angle apparatus, refractometer, etc. The theoretical discussion is simply presented and good, and embraces all the essentials.

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MEAD, W. J. "Occurrence and Origin of the Bauxite Deposits of Arkansas," *Econ. Geol.*, X (1915), 28–54, pls. 5, figs. 7.

The writer believes that the bauxite of Arkansas is derived from the weathering of the underlying syenite, and gives analyses showing the transition. Previous writers maintained that the deposits were chemical sediments or due to the action of hot springs from the still heated syenite.

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MENNELL, F. P. *A Manual of Petrology.* Chapman and Hall, London, 1913. Pp. iv+256, figs. 122.

This little book is an enlargement of Mennell's *Introduction to Petrology*, which was published in 1909. The book has been practically rewritten, new cuts have been added, and the form has been considerably changed. Fifteen pages are devoted to the general properties of minerals, 11 to optical methods of determination, 53 to the rock-forming minerals, 38 to general petrology, 56 to the igneous rocks, 12 to the sediments, 32 to metamorphism, 7 to weathering, 10 to the distribution of the chemical elements, 9 to radio-activity, and 7 to the collection and preparation of material.

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MERWIN, H. E. "Measurement of the Extraordinary Refractive Index of a Uniaxial Crystal by Observations in Convergent Light on a Plate Normal to the Optic Axis," *Jour. Washington Acad. Sci.*, IV (1914), 530–34.

MILLER, WILLET G., and KNIGHT, CYRIL W. *The Pre-Cambrian Geology of Southeastern Ontario.* Report Bureau Mines, XXII, Part II, Toronto, 1914. Pp. vi+151, figs. 67, pls. 4, maps 7, bibliographies.

The oldest rocks of the region are essentially green schists of igneous origin, which were extruded during the Keewatin period. In other parts of Ontario this was a period of great volcanic activity, and enormous quantities of rock were erupted. Succeeding this active period came one of sedimentation during which the Grenville series, variously estimated at from 50,000 to 94,406 feet in thickness, and consisting of crystalline limestone, greywacke, quartzite, and slate and iron formations, was laid down. During Laurentian times both the Keewatin and Grenville rocks were invaded by great masses of granite and syenite. This caused a folding and crumpling of the older rocks, and their alteration to schists and gneisses. Injection schists appear in certain places. Later, erosion removed much of the Keewatin and Grenville material and exposed the deep-lying igneous rocks. The region now became partially or entirely submerged and beds of conglomerate and quartzite of the Hastings series were deposited. The youngest pre-Cambrian rocks are post-Hastings, and include granite, diabase, and basalt. During the Paleozoic the surface sank below sea-level, and limestones, sandstones, and shale were deposited, and these were later elevated to their present position.

Numerous analyses are given, but little attempt has been made to describe the rocks petrographically.